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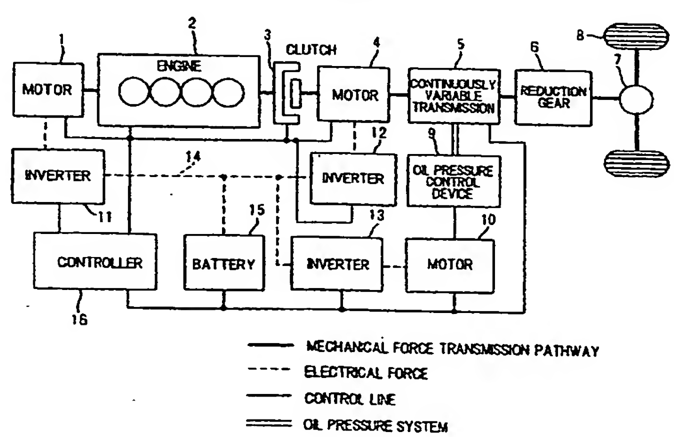
(54) **Drive power control device for hybrid vehicle**

(57) A target drive torque is calculated based on a detected value for vehicle speed and a detected value for an accelerator pedal depression amount. A generator torque is calculated for a motor(1,4) based on a battery SOC. An engine(2) is controlled to a torque value which achieves a target drive torque and a generator torque as a target engine torque. The motor(1,4) is controlled to a value which is the difference of a target drive torque and an engine torque estimation value as a target motor torque. In this way, a required generator amount may be achieved under steady-state conditions and it is possible to satisfy charge conditions of the battery(15). In addition, required drive force by the driver can be achieved during transition running and responsive acceleration and deceleration can be performed.

FIG. 1



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motor 4 is the source of drive power of the vehicle. The drive force of the engine 2 and/or the motor 4 is transmitted to the drive wheels through the continuously variable transmission 5, the reduction gear 6 and the differential gear 7. A drive ratio in the continuously variable transmission 5 is varied on the basis of an oil pressure supplied from an oil pressure control device. An oil pump (not shown) of the oil pressure control device 9 is driven by a motor 10.

[0011] The motors 1, 4, 10 are alternating current electrical motors such as a three phase synchronous electric motor or a three phase induction electric motor. The motor 1 is used mainly to start the engine and to generate electricity. The motor 4 is used mainly to drive and brake the vehicle. The motor 10 is used to drive the oil pump of the oil pressure control device 9. The motors 1, 4, 10 are not limited to an alternating current motor and it is possible to use a direct current motor. When the clutch 3 is engaged, it is possible to use the motor 1 to drive and brake the vehicle and use the motor 4 to start the engine and generate electricity.

[0012] The clutch 3 is a powder clutch which can regulate the size of the transmitted torque. A single dry type clutch or a multiple wet type clutch may be used as a clutch. The continuously variable transmission 5 is a toroidal or a belt-type continuously variable transmission in which a drive ratio may be continuously varied.

[0013] The motors 1, 4, 10 are driven by inverters 11, 12, 13. When a direct current motor is used as a motor 1, 4, 10, a DC/DC converter may be used instead of the inverter. The inverters 11 ~ 13 are directly connected to a main battery 15 through a common DC link 14. Direct current electrical power from the main battery 15 is converted to an alternating current and supplied to the motor 1, 4, and 10. At the same time, an alternating current generated from the motors 1, 4 is converted to a direct current and charges the main battery.

[0014] Since the inverters 11 ~ 13 are mutually connected through the DC link 14, it is possible to supply electrical power generated by the motor during regenerative operation directly to the other motor during running without passing the main battery 15.

[0015] It is possible to use all kinds of batteries such as lithium, ion batteries, nickel batteries, hydrogen batteries and lead batteries or an electric motor double capacitor, the so-called "power capacitor" as the main battery.

[0016] The controller 16 is provided with a microcomputer, related components and various actuators. The controller 16 controls the output torque or rotation speed of the engine 2, the transmission torque of the clutch 3, the output torque or rotation speed of the motor 1, 4, 10 and the drive ratio of the continuously variable transmission 5.

[0017] As shown in Figure 2, the engine key switch 20, the transmission select lever switch 21, the accelerator sensor 22, the brake switch 23, the vehicle speed sensor 24, the battery temperature sensor 25, the battery state-of-charge (hereafter SOC) detection device 26, the engine rotation sensor 27 and the throttle aperture sensor 28 are connected to the controller 16,

[0018] The engine key switch 20 is placed in the ON position by setting the vehicle key in the ON or the START position. The transmission select lever switch 21 places the P, N, R, D switches in the ON position in response to placing the transmission select lever position to parking P, neutral N, reverse R and drive D.

[0019] The accelerator sensor 22 detects the amount of depression *aps* (hereafter accelerator aperture) of the accelerator pedal. The brake switch 23 detects the state of depression (here "switch ON") of the brake pedal. The vehicle speed sensor 24 detects the running speed *Vsp* of the vehicle. The battery temperature sensor 25 detects the temperature *Tb* of the main battery 15. The battery SOC detection device 26 detects the SOC (state of charge) of the main battery 15. The engine rotation sensor 27 detects the rotation speed *Ne* of the engine 2 and the throttle aperture sensor 28 detects the throttle valve aperture θth of the engine 2.

[0020] The controller 16 is connected to the fuel injection device 30 of the engine 2, the ignition device 31, the value timing regulation device 32 and the like. The controller 16 controls the fuel injection device 30 and regulates the fuel injection amount as well as the termination and supply of fuel to the engine 2. The ignition device 31 is controlled to perform ignition of the engine 2. The controller 16 controls the valve timing regulation device 32 and the closure period of the air intake valve of the engine 2. The controller 16 is supplied with a low voltage power source by the auxiliary battery 33.

[0021] Figure 3 and Figure 4 show the arrangement of the power train.

[0022] The disposition of the engine 2 and the motor 1 on the input side of the clutch 3 may comprise the motor 1 being upstream of the engine 2 as shown in Figure 3 or downstream of the engine 2 as shown in Figure 4.

[0023] In the arrangement shown in Figure 3, the output shaft of the engine 2 is directly connected to the input shaft of the clutch 3. At the same time, the output shaft of the engine 2 is connected to the output shaft of the motor 1 by a belt or a gear. In the arrangement shown in Figure 4, the output shaft of the engine 2 is directly connected to the input shaft of the clutch 3 by passing through a rotor of the motor 1. Thus the input side of the clutch 3 is formed on a single axis.

[0024] The arrangement of the continuously variable transmission 5 and the motor 4 on the output side of the clutch 3 may comprise the arrangement of the motor 4 upstream of the continuously variable transmission 5 as shown in Figure 3 or the arrangement of the motor 4 downstream of the continuously variable transmission 5 as shown in Figure 4. In the arrangement shown in Figure 3, the output shaft of the clutch 3 is directly connected to the input shaft of the continuously variable transmission 5 by passing through the rotor of the motor

tion value of a target drive torque and a generator torque. The motor is controlled by a target motor torque representing a difference between a target drive torque and an engine torque estimation value.

[0040] Thus when the value of the target motor torque is positive, the deficit of the engine torque is corrected by the motor output. When the value is negative, the motor functions as a generator to charge the battery.

[0041] As shown above, basically a target input torque *tTs* is generated by the engine 2. However when there is a deficit in the absolute value of the output of the engine during transitional running condition for example, or when there is a deficit in the output due to a response delay, a torque is generated by the motor 4 as a target motor torque *tTm*. When the output of the engine 2 is assisted by generating a torque by the motor 4 but on the other hand generation of electricity is performed by the other motor 1 or is required, generation of electricity is not performed by the motor 1 and the amount of engine assist due to the motor 4 is decreased to that degree.

[0042] In this way, it is possible to divert a real engine torque *Te* to a drive component of the vehicle from an electricity generating component. This has the same effect as assisting the engine 2 by generating a torque from the motor 4.

[0043] When the engine 2 is assisted by generating a torque from the motor 4 while generating electricity with the motor 1, energy loss is increased by generator loss from the motor 1 and drive power loss from the motor 4. However when the engine 2 is assisted by the motor 4, it is possible to reduce generator loss from the motor 1 and drive power loss from the motor 4 by reducing the assist amount of the motor 4 by not generating electricity with the motor 1. Thus overall efficiency can be improved.

[0044] According to the drive control method of the present embodiment, as desclosed above, it is possible to satisfy the required generator amount and drive force during steady-state running and efficiently assist the deficit of engine torque during transitional running with the motor.

[0045] Figure 7 is a time chart showing control characteristics during acceleration.

[0046] The accelerator pedal aperture *aps* is increased by depressing the acceleration pedal during running. Thus the target drive torque *tTd* in the drive shaft is increased and the target input rotation speed *tNi* of the continuously variable transmission 5 is increased in order to realize a target drive torque *tTd* at that vehicle speed *Vsp*.

[0047] When a generator torque *tTg* has the value 0, a target input torque *tTe* is calculated from a target drive torque *tTd* based on a real input rotation speed *Ni* (actual drive ratio *rG*) of the continuously variable transmission 5. Furthermore a target input torque *tTs* is calculated by adding a torque *Ti* of the inertial correction value due to variable control.

[0048] Basically, although the engine 2 is controlled by a target input torque *tTs* as a target engine torque, there is a limit to engine torque. Furthermore since there is a response delay, when there is a difference between target input torque *tTs* and a real engine torque *Te*, the difference is taken to be a target motor torque *tTm* and the engine 2 is assisted by the motor 4.

[0049] On the other hand, when generation of electricity is required and the generator torque *tTg* does not have the value of 0, a target input torque *tTe* is calculated from the addition amount *vtTd* of the target drive torque *tTd* and the generator torque *tTg* based on a real input rotation number *Ni* (actual drive ratio *rG*) of the continuously variable transmission 5. A target input torque *tTs* is calculated by adding an inertial torque correction amount *Ti* due to variable control.

[0050] Similar to the situation in which no generation of electricity is required, the engine 2 basically is controlled to a target input torque *tTs* as a target engine torque. However since a target engine torque exceeds a maximum value or there is a response delay in reaching an engine torque, when only the engine torque is insufficient, firstly a generator torque of the engine 2 may be diverted to a drive component by reducing the generator amount of the motor 1. When the drive torque is still insufficient, the engine 2 may be assisted by the motor 4. Once the real engine torque *Te* exceeds a target input torque *tTs* - *tTgi* (not including the generator torque), electricity generation by the motor 1 may be recommenced by terminating the engine assist of the motor 4.

[0051] Figure 8 to Figure 11 show the simulation result of control characteristics under different running conditions.

[0052] Figure 8 shows the result of depressing the acceleration pedal when the vehicle is running at 30 km/h with a generator amount of 0. Figure 9 shows the result of depressing the acceleration pedal when the vehicle is running at 30 km/h with a generator amount of 10kw. Figure 10 shows the result of depressing the acceleration pedal when the vehicle is running at 30 km/h with a generator amount of 0 and subsequently releasing the acceleration pedal. Figure 11 shows the result of depressing the acceleration pedal when the vehicle is running at 30 km/h with a generator amount of 10kw and subsequently releasing the accelerator pedal.

[0053] The real engine torque *Te* is created by a response delay with respect to the target engine torque *tTs* and is rapidly assisted by an assist torque *Tm* due to the motor 4 and the vehicle varies speed by the total torque of these two values *Te+Tm*.

[0054] However the real drive torque *Td* in the drive shaft undergoes a response delay on comparison with a target drive force *tTd* since creation of an actual input rotation speed *Ni* in the continuously variable transmission 5 undergoes a response delay.

[0055] When the generator amount takes a value of 0, the motors 1 and 4 generate an acceleration force when

said target drive torque and said engine torque estimated value as a target motor torque.

2. A drive power control device for a hybrid vehicle according to Claim 1 wherein said controller(16) controls an output of said motor(1,4) to assist the rotation of said engine(2) when said target drive torque is greater than said engine torque estimated value and controls a generation of electricity by said motor(1,4) when said target drive torque is smaller than said engine torque estimated value.

3. A drive power control device for a hybrid vehicle according to Claim 1 wherein said controller(16) controls said engine(2) by applying a drive correction to said target engine torque.

4. A drive power control device for a hybrid vehicle according to Claim 1 wherein said controller(16) controls said motor(1,4) by the difference of a value of applying a delay correction value to said target drive torque and said engine torque estimated value as a target motor torque.

5. A drive power control device for a hybrid vehicle according to Claim 4 wherein said controller(16) performs a delay correction on said target drive torque to suppress resonance of the vehicle drive system.

6. A drive power control device for a hybrid vehicle according to Claim 1 wherein said controller(16) adds an inertial correction torque accompanying variable control in a transmission to said target drive torque.

7. A drive power control device for a hybrid vehicle according to Claim 1 wherein said controller(16) further determines whether or not to output said target motor torque by said motor based on a condition of said motor(1,4) and said detected state of charge value of said battery(15), and
enriches an air-fuel ratio temporarily to achieve said target engine torque when it is determined not to output said target motor torque.

8. A drive power control device for a hybrid vehicle according to Claim 1 wherein said motor(1,4) is comprised from a plurality of motors(1,4) and
said controller(16) further controls and calculates cooperatively a target torque of said plurality of motors(1,4) to avoid a situation in which the generation of electricity by one motor(1,4) coincides with the output of torque by another motor(1,4).

FIG.2

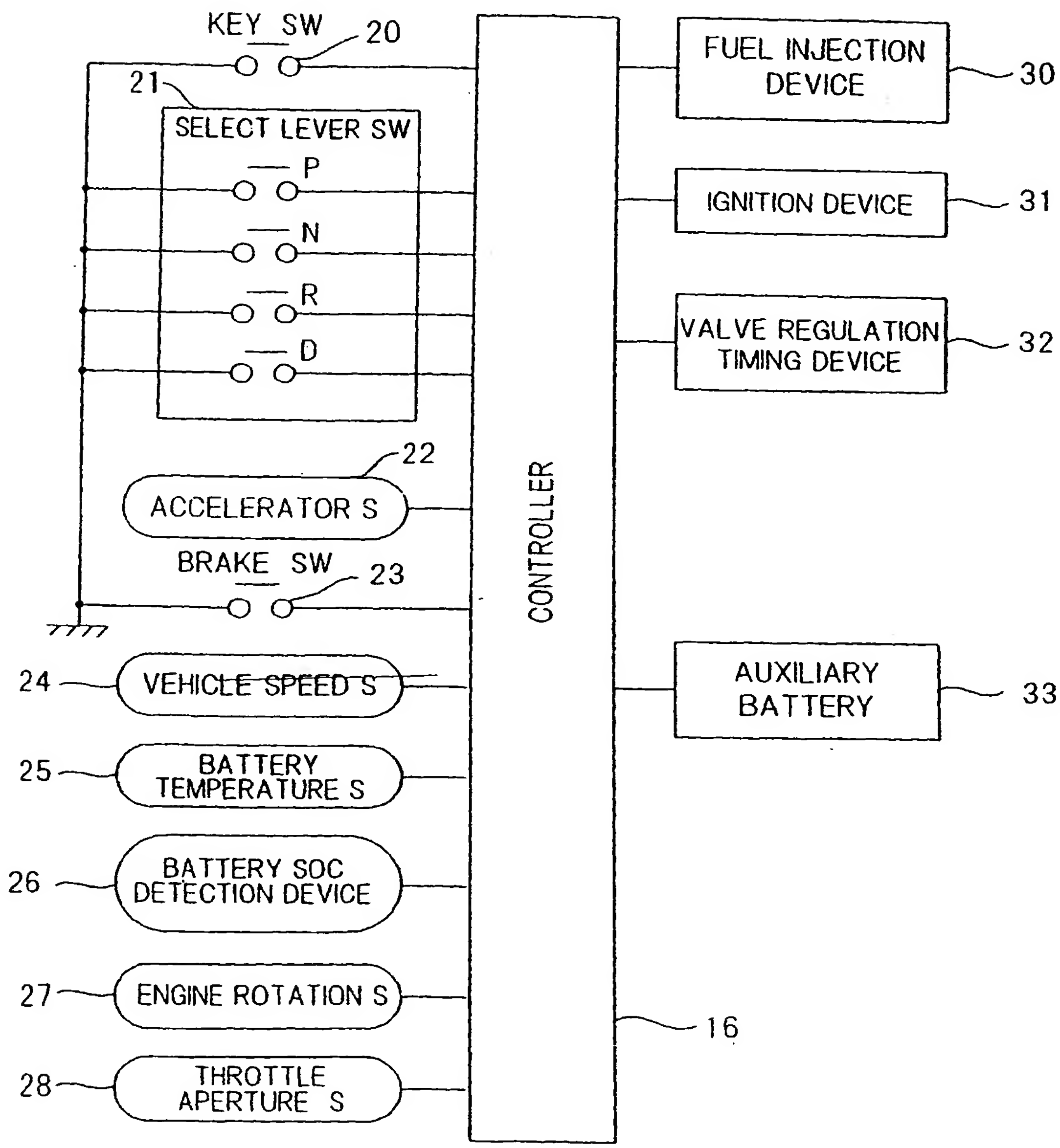
KEY SW
20
21
SELECT LEVER SW
P
N
R
D
22
ACCELERATOR S
BRAKE SW
23
24
VEHICLE SPEED S
25
BATTERY TEMPERATURE S
26
BATTERY SOC DETECTION DEVICE
27
ENGINE ROTATION S
28
THROTTLE APERTURE S
CONTROLLER
16
FUEL INJECTION DEVICE
30
IGNITION DEVICE
31
VALVE REGULATION TIMING DEVICE
32
AUXILIARY BATTERY
33

FIG. 4

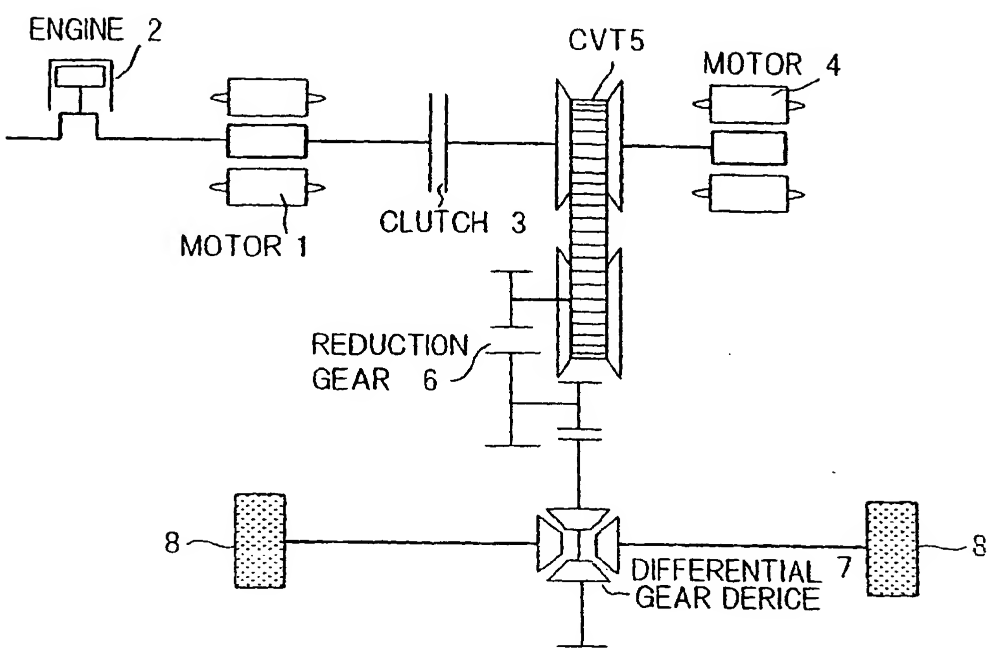
ENGINE 2
CVT5
MOTOR 4
CLUTCH 3
MOTOR 1
REDUCTION GEAR 6
8
DIFFERENTIAL GEAR DERICE 7
8

FIG.6

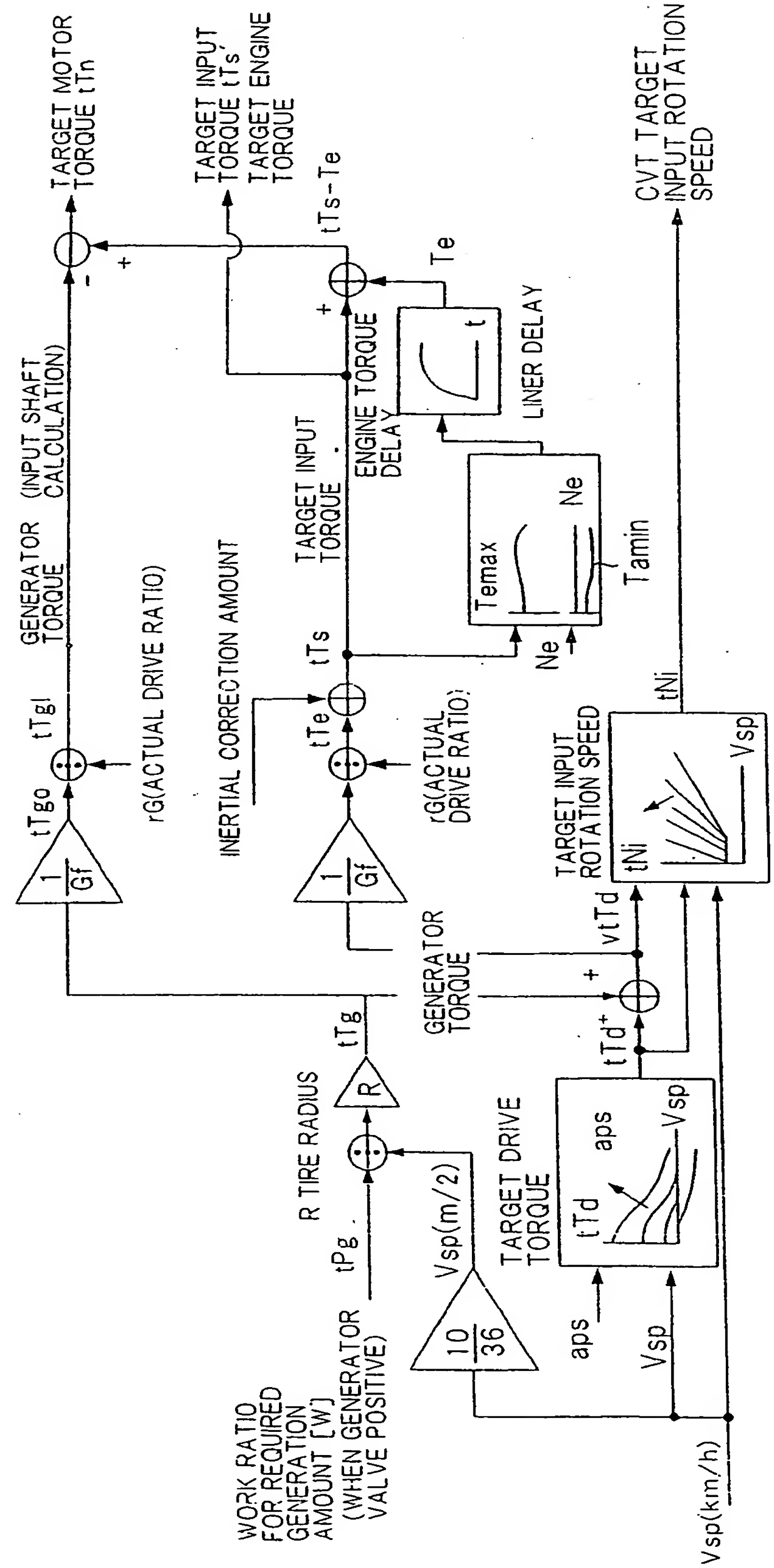
TARGET MOTOR TORQUE tTn
TARGET INPUT TORQUE tTs'
TARGET ENGINE TORQUE
tTs-Te
CVT TARGET INPUT ROTATION SPEED
Te
LINER DELAY
ENGINE TORQUE DELAY
GENERATOR TORQUE
(INPUT SHAFT CALCULATION)
TARGET INPUT TORQUE
Temax
Ne
Tamin
rG(ACTUAL DRIVE RATIO)
INERTIAL CORRECTION AMOUNT
tTgo
tTg!
tTe
tTs
tNi
1/Gf
rG(ACTUAL DRIVE RATIO)
TARGET INPUT ROTATION SPEED
Vsp
GENERATOR TORQUE
vtTd
tTd'
R TIRE RADIUS
tTg
R
tPg
Vsp(m/2)
TARGET DRIVE TORQUE
tTd
aps
10/36
WORK RATIO FOR REQUIRED GENERATION AMOUNT [W] (WHEN GENERATOR VALVE POSITIVE)
Vsp(km/h)

FIG.8

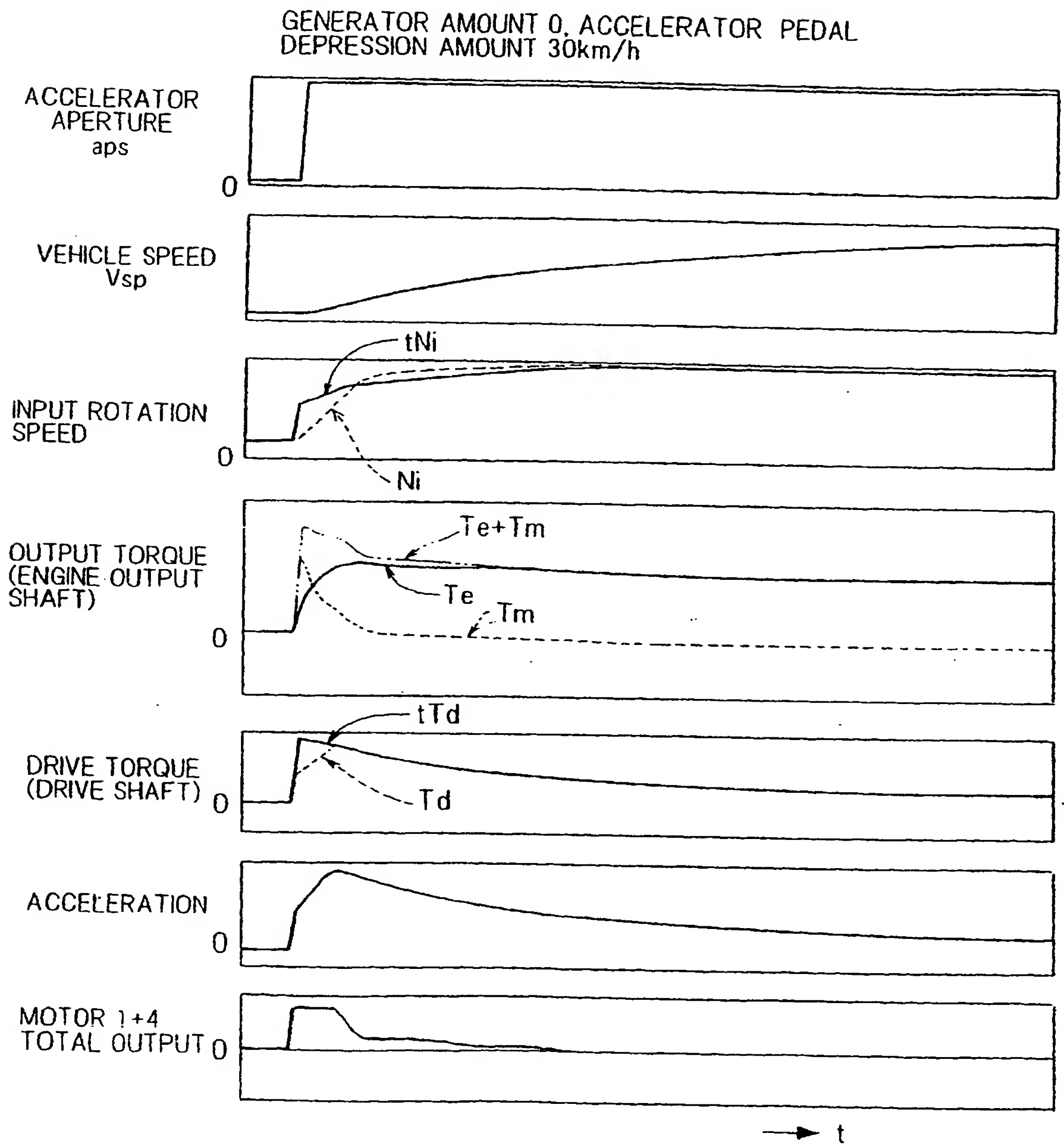
GENERATOR AMOUNT 0, ACCELERATOR PEDAL DEPRESSION AMOUNT 30km/h
ACCELERATOR APERTURE aps
0
VEHICLE SPEED Vsp
tNi
INPUT ROTATION SPEED
0
Ni
Te+Tm
OUTPUT TORQUE (ENGINE OUTPUT SHAFT)
Te
Tm
0
tTd
DRIVE TORQUE (DRIVE SHAFT)
0
Td
ACCELERATION
0
MOTOR 1+4 TOTAL OUTPUT
0
t

FIG. 10

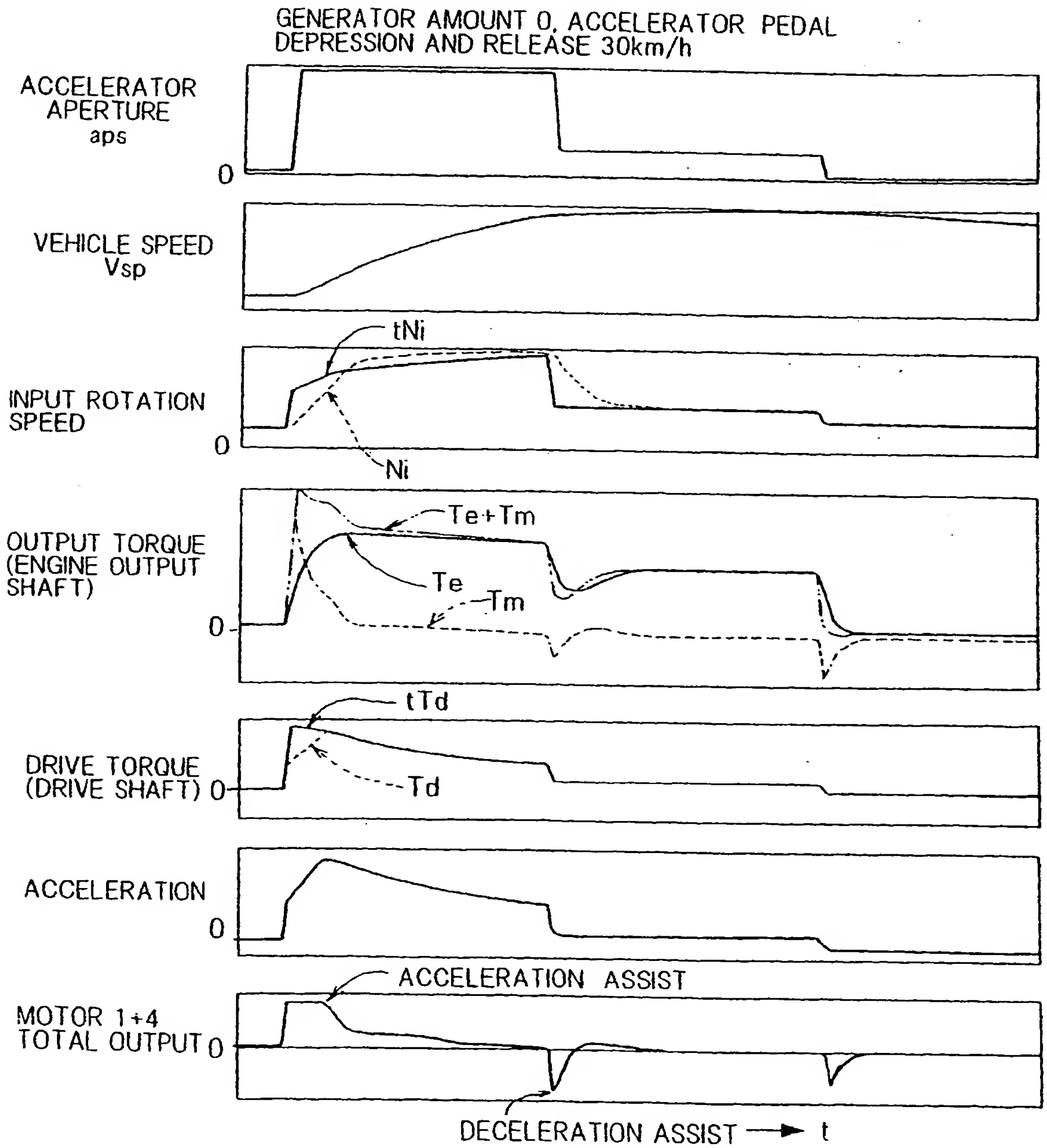
GENERATOR AMOUNT 0, ACCELERATOR PEDAL DEPRESSION AND RELEASE 30km/h
ACCELERATOR APERTURE aps
0
VEHICLE SPEED Vsp
tNi
INPUT ROTATION SPEED
0
Ni
Te+Tm
OUTPUT TORQUE (ENGINE OUTPUT SHAFT)
Te
Tm
0
tTd
DRIVE TORQUE (DRIVE SHAFT) 0
Td
ACCELERATION
0
ACCELERATION ASSIST
MOTOR 1+4 TOTAL OUTPUT 0
DECELERATION ASSIST
t

FIG. 12

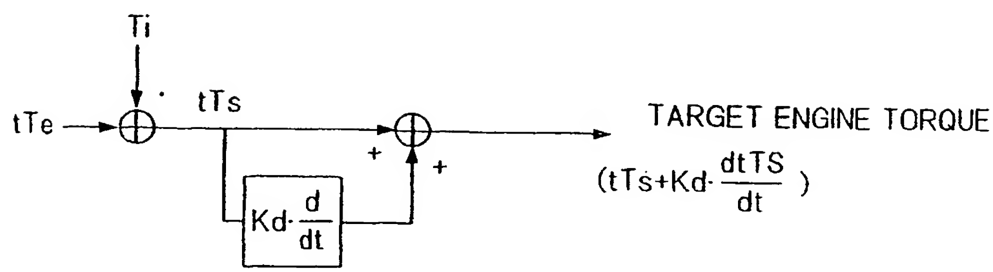
Ti
tTe
tTs
+
+
Kd· d/dt
TARGET ENGINE TORQUE
(tTs+Kd· dtTS/dt)

FIG. 13

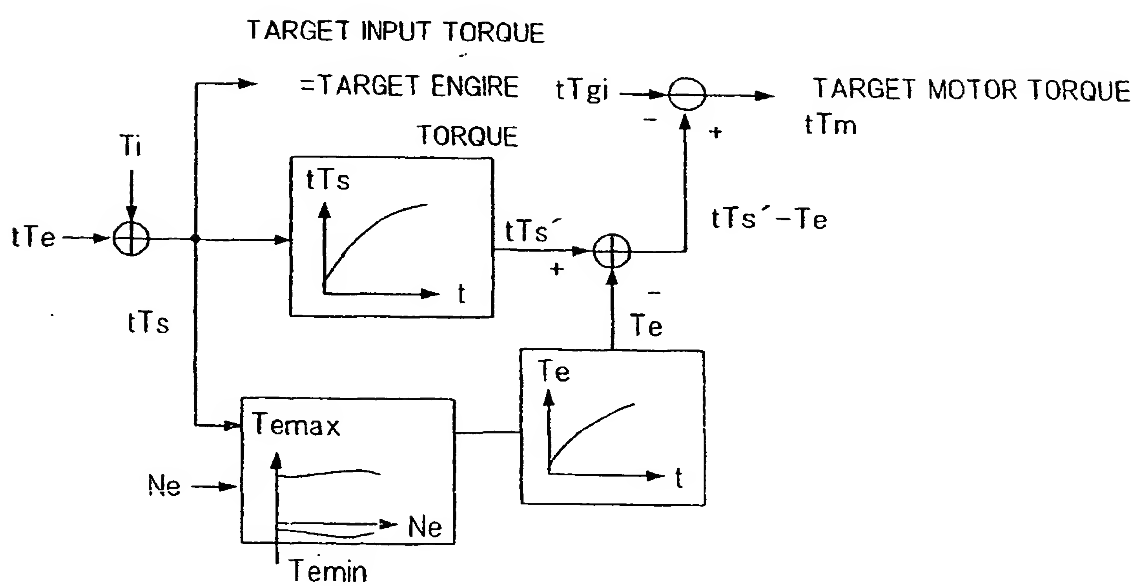
TARGET INPUT TORQUE
=TARGET ENGIRE
TORQUE
tTgi
TARGET MOTOR TORQUE
tTm
Ti
tTe
tTs
t
tTs´
+
+
-
-
tTs´-Te
Te
tTs
Te
t
Temax
Ne
Ne
Temin

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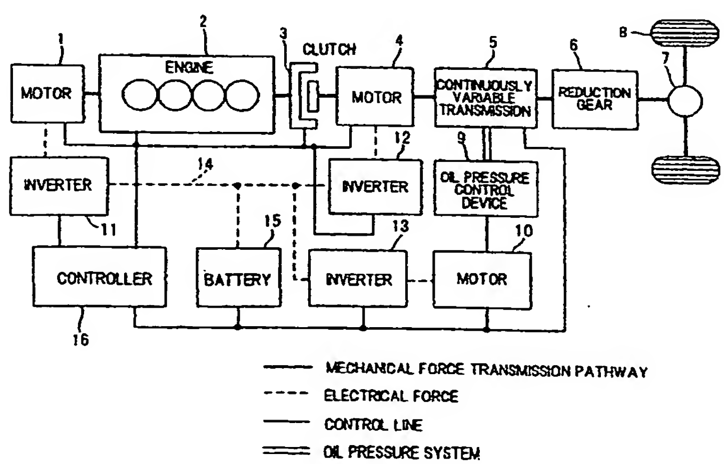
FIG. 1



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EP 99 11 0638

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		US 5984033 A	16-11-1999

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